'49

Department of Agriculture
and Fisheries for Scotland

The Design and Testing of a Divided Trawl for Comparative Fishing Experiments

Scottish Fisheries Research
Report Number 49 1990
ISSN 0308 8022

LIBRARY
JAN 7 1991
National Marine Fisheries Service
2570 Dole Street
Honolulu, Hawaii

J H B Robertson,
A M Shanks and
R J Kynoch

PREVIOUS SCOTTISH FISHERIES RESEARCH REPORTS

1975 No. 1 The Aberdeen Single-Anchor Mooring.
By R. Payne, 7 pp.

No. 2 The Aberdeen Shallow Water Current Meter Mooring.
By R. Payne, 13 pp.

1976 No. 3 The Bridger Version of the Gulf III High Speed Plankton Sampler.
By J.A. Adams, 42 pp.

No. 4 Some Parasites of Plaice *Pleuronectes platessa* L. in Three Different Farm Environments.
By K. MacKenzie, A. H. McVicar and I.F. Waddell, 14 pp.

No. 5 Simulation of Vertical Structure in a Planktonic Ecosystem.
By J.H. Steele and E.W. Henderson, 27 pp.

No. 6 The Intertidal Fauna of Sandy Beaches — A Survey of the Scottish Coast.
By A. Eleftheriou and A.D.McIntyre, 61 pp.

1977 No. 7 A Net Drag Formula for Pelagic Nets.
By Aenea J.Reid, 12 pp.

No. 8 The Aberdeen Sedimentation Trap and its Moorings.
By R. Payne and J.M. Davies, 11 pp.

No. 9 A Preliminary Model of Shear Diffusion and Plankton Populations.
By G.T. Evans, J.H. Steele and G.E.B. Kullenberg, 19 pp.

No. 10 Diving Observations on the Efficiency of Dredges used in the Scottish Fishery for the Scallop, *Pecten maximus* (L.).
By C.J. Chapman, James Mason and J.A.M. Kinnear, 16 pp.

1978 No. 11 Comparative Fishing for Flatfish using a Beam Trawl fitted with Electric Ticklers.
By Peter A.M. Stewart, 10 pp.

No. 12 The Value of Direct Observation Techniques by Divers in Fishing Gear Research.
By J. Main and G.I. Sangster, 15 pp.

1979 No. 13 The Occurrence of Plerocercoids of Diphyllobothrium spp. in Wild and Cultured Salmonids from the Loch Awe Area.
By R. Wootten and John W. Smith, 8 pp.

No. 14 A Study of Bottom Trawling Gear on both Sand and Hard Ground.
By J. Main and G.I. Sangster, 15 pp.

No. 15 The Coastal Movements of Returning Atlantic Salmon, *Salmo salar* L.
By A.D. Hawkins, G.G. Urquhart and W.M.Shearer, 14 pp.

No. 16 Hydrodynamic Characteristics of Trawl Warps.
By D.N. MacLennan, 10 pp.

No. 17 Some Parasites and Diseases of Blue Whiting, *Micromesistius poutassou* (Risso), to the North and West of Scotland and at the Faroe Islands.
By K. MacKenzie, 14 pp.

1980 No. 18 Changes in the Respiration and Blood Circulation of Cod, *Gadus morhua* L., Induced by Exposure to Pollutants.
By A.D.F. Johnstone and A.D. Hawkins, 18 pp.

1981 No. 19 Survey of Trace Elements in Fish and Shellfish landed at Scottish Ports 1975–76.
By I.M. Davies, 28 pp.

No. 20 A Study of the Sand Clouds Produced by Trawl Boards and their Possible Effect on Fish Capture.
By J. Main and G.I. Sangster, 20 pp.

1981 No. 21 Orientation and Energetic Efficiency in the Offshore Movements of Returning Atlantic Salmon *Salmo salar* L.
By G.W. Smith, A.D. Hawkins, G.G. Urquhart and W.M. Shearer, 22 pp.

No. 22 The Theory of Solid Spheres as Sonar Calibration Targets.
By D.N. MacLennan, 17 pp.

No. 23 A Study of the Fish Capture Process in a Bottom Trawl by Direct Observations from a Towed Underwater Vehicle.
By J. Main and G.I. Sangster, 23 pp.

1982 No. 24 A Study of Separating Fish from *Nephrops norvegicus* L. in a Bottom Trawl.
By J. Main and G.I. Sangster, 8 pp.

No. 25 Target Strength Measurements on Metal Spheres.
By D.N. MacLennan, 11 pp.

No. 26 A Study of a Multi-Level Bottom Trawl for Species Separation Using Direct Observation Techniques.
By J. Main and G.I. Sangster, 17 pp.

1983 No. 27 Fish Reactions to Trawl Gear — A Study Comparing Light and Heavy Ground Gear.
By J. Main and G.I. Sangster, 17 pp.

No. 28 Guidelines for the Use of Biological Material in First Order Pollution Assessment and Trend Monitoring.
By G. Topping, 28 pp.

No. 29 TUV II — A Towed Wet Submersible For Use in Fishing Gear Research.
By J. Main and G.I. Sangster, 19 pp.

No. 30 The United Kingdom Fishery for the Deep Water Shrimp *Pandalus borealis* in the North Sea.
By F.G. Howard, 16 pp.

Department of Agriculture
and Fisheries for Scotland

The Design and Testing of a Divided Trawl for Comparative Fishing Experiments

J H B Robertson,
A M Shanks and
R J Kynoch

Scottish Fisheries Research
Report Number 49 1990
ISSN 0308 8022

The Design and Testing of a Divided Trawl for Comparative Fishing Experiments

J H B Robertson, A M Shanks and R J Kynoch

Marine Laboratory, Aberdeen

Introduction

Fishery management regimes often restrict mesh size as a means of controlling what is retained within cod-ends. It is important to know what effect a change in mesh size will have on the catch composition in the cod-end. One of three techniques is usually applied to the measurement of cod-end selectivity, namely, the small mesh cod-end cover, the alternate haul method, or the "trouser trawl". There are advantages and drawbacks associated with each experimental method. Although the covered cod-end method requires fewer hauls to estimate selectivity, the small mesh cover may mask the cod-end meshes, block fish escape and bias the results. The alternate haul method requires one haul with a small mesh cod-end to sample the fish population and a second "alternate" tow with the test cod-end; the difficulty is that the population sampled may vary in both numbers and size range between hauls. The trouser trawl method has the advantage of taking simultaneous samples in two cod-ends but might suffer from asymmetry. The cod-ends may fish unequally and a true comparison cannot then be made. All these techniques are used to gather specific information on the mesh selection characteristics, such as 50% retention length, selection range and selection factor (as defined by Pope, Margetts, Hamley and Akyuz, 1975), or to make catch comparisons between cod-ends.

The accuracy of these methods was discussed by Davis (1934), Smolowitz (1983), Beverton and Holt (1957), and Pope *et al.* (1975). All three techniques are open to the criticism that the cod-end is not being used as in commercial fishing. A trawl for cod-end selection studies which simulates commercial conditions more closely is described here. It is designed to tow two cod-ends simultaneously, and is named the "divided" trawl (Fig. 1). It is a variant of the trouser trawl but, unlike many trouser trawl designs (eg those of Russell and Edser, 1926; Davis, 1934; Herrington, 1936; and Cooper and Hickey, 1987), the two sides of the divided trawl are completely separate along the length of the net. Both sides are attached at the front to the same footrope and headline. The main advantage of such a design is that the same population of fish is being sampled by the two cod-ends under test and it may be more resistant to mechanical distortion and asymmetry than the trouser trawl. Small mesh covers, which may mask the cod-end meshes, are not required.

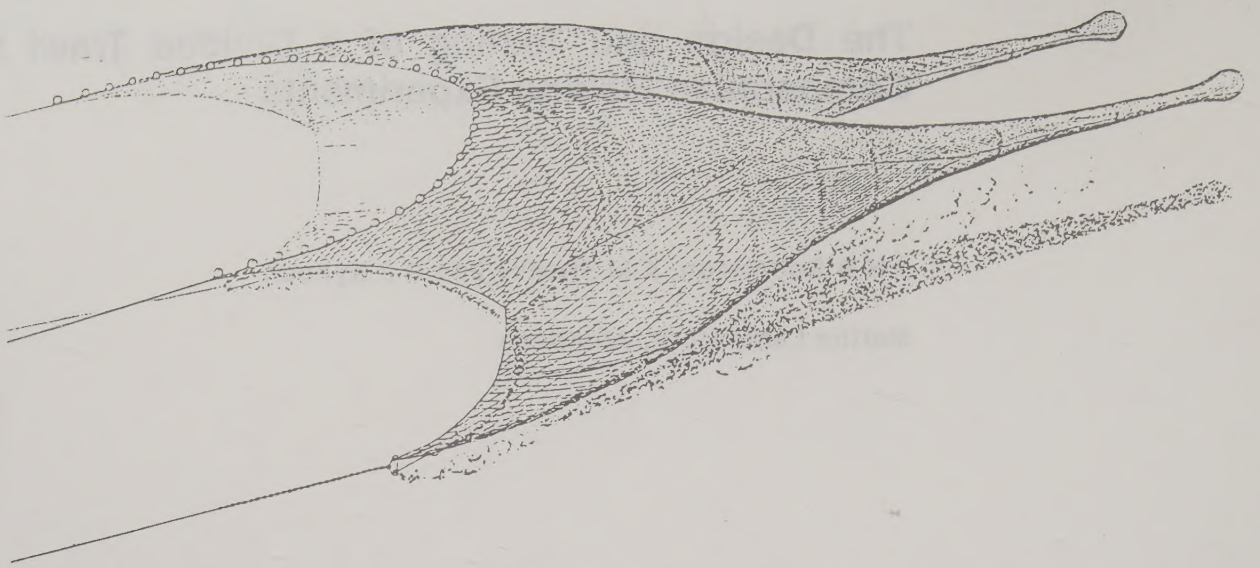

Figure 1. A schematic representation of the divided trawl

Before carrying out selection or catch comparison trials with the new net, its catching performance had to be thoroughly examined and several questions had to be answered. For example, do the fish which are herded into the mouth of the trawl really divide evenly into each side? It is essential that they do so to ensure that each cod-end samples the same number and size range of fish. Is fish behaviour altered by any aspect of the design of the trawl relative to that of ordinary trawls? These questions were investigated using under-water television to observe the trawl. In addition, fishing trials of the divided trawl having identical cod-ends were performed to check that equal catches were taken on each side.

Method

The TV and fishing trials were carried out on the chartered fishing vessel"Orkney Reiver" K49. At the time of the TV trials she was a 24.3 m (80 feet) over-all length, steel-hulled, three-quarter length, shelter-decked trawler with a 620 hp diesel engine. When the fishing trials were conducted the vessel had been lengthened by 4.6 m (15 feet).

Under-water Observations

Under-water observations were made using the remote controlled towed vehicle (RCTV) described by Priestley, Wardle and Hall (1985). This carried a low light television camera and a photographic stills camera, both mounted on a steerable platform. Observations were made on the trawl during February 1987 on commercial fishing grounds at depths of between 18.3 and 91.5 m (10 and 50 fm) using various rigs and towing speeds. The effect on the trawl shape of two different types of otterboard was observed. In addition, fish behaviour within the trawl mouth and along the net into the cod-end was examined.

Observation within the mouth of the trawl was difficult since the observation vehicle apparently affected fish behaviour. However, observations were conducted mainly from outside the trawl mouth with the RCTV either clear of the sides or above the headline. From outside the trawl, fish were observed moving along the body of the trawl and into the extensions and cod-ends.

Fishing Trials

The fishing trials were conducted from 21 to 27 January 1988 in fishing areas to the east and west of Fair Isle and Orkney. Hauls were made during daylight and darkness hours. The cod-ends were exactly similar, being 6.1 m long (20 feet stretched mesh length) and constructed with 90 mm nominal double braided 3.5 mm diameter polyethylene netting. Care was taken to ensure that both sides of the trawl were exactly the same in every detail of mesh size, twine diameter, colour of netting and components. Figure 2 shows the technical specifications of the trawl. Mesh measurements of the cod-ends and extensions were exactly similar on both sides of the gear. Measurements taken regularly with an ICES mesh measuring gauge set at 4 kg tension were 90 mm for the extensions and 87 mm for the cod-ends.

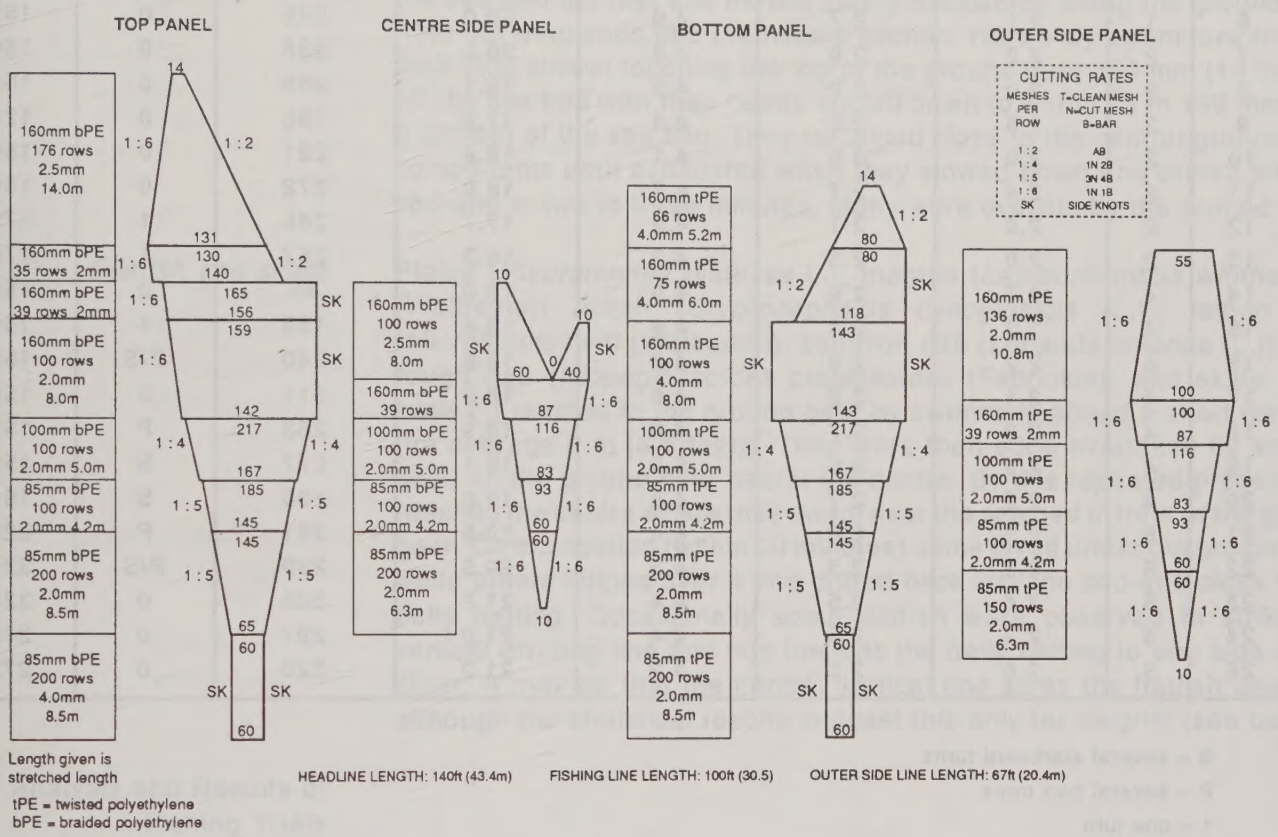
TOP PANEL
CENTRE SIDE PANEL
BOTTOM PANEL
OUTER SIDE PANEL
CUTTING RATES
MESHES PER ROW
T=CLEAN MESH N=CUT MESH B=BAR
1:2 AB
1:4 1N 2B
1:5 3N 4B
1:6 1N 1B
SK SIDE KNOTS
160mm bPE 176 rows 2.5mm 14.0m
160mm bPE 35 rows 2mm
160mm bPE 39 rows 2mm
160mm bPE 100 rows 2.0mm 8.0m
100mm bPE 100 rows 2.0mm 5.0m
85mm bPE 100 rows 2.0mm 4.2m
85mm bPE 200 rows 2.0mm 8.5m
85mm bPE 200 rows 4.0mm 8.5m
160mm bPE 100 rows 2.5mm 8.0m
160mm bPE 39 rows
100mm bPE 100 rows 2.0mm 5.0m
85mm bPE 100 rows 2.0mm 4.2m
85mm bPE 200 rows 2.0mm 6.3m
160mm tPE 66 rows 4.0mm 5.2m
160mm tPE 75 rows 4.0mm 6.0m
160mm tPE 100 rows 4.0mm 8.0m
100mm tPE 100 rows 2.0mm 5.0m
85mm tPE 100 rows 2.0mm 4.2m
85mm tPE 200 rows 2.0mm 8.5m
160mm tPE 136 rows 2.0mm 10.8m
160mm tPE 39 rows 2mm
100mm tPE 100 rows 2.0mm 5.0m
85mm tPE 100 rows 2.0mm 4.2m
85mm tPE 150 rows 2.0mm 6.3m
Length given is stretched length
tPE = twisted polyethylene
bPE = braided polyethylene
HEADLINE LENGTH: 140ft (43.4m)
FISHING LINE LENGTH: 100ft (30.5)
OUTER SIDE LINE LENGTH: 67ft (20.4m)

Figure 2. The divided trawl net specifications

At the end of a tow the cod-ends were emptied into separate ponds on the deck, taking care that species were well mixed. The contents from each cod-end were boxed separately (one box held approximately 44.5 kg) and a total box count was taken for each cod-end. A sample consisting of two to eight boxes was taken from each cod-end for measuring fish lengths. The fish numbers at each length were then raised to the total number caught in each cod-end. In some hauls all the fish were measured. Cod-ends were switched from side to side three times during the cruise, after hauls 6, 14 and 20 (Table I).

Gear measurements such as headline height and wing and otterboard spreads were taken each haul using Scanmar instrumentation. The headline height and wing end spread data were logged on a BBC computer. Navigational details (latitude, longitude, ground speed) were also logged on the computer from a Shipmate RS4000. All the data were both logged onto disc and printed out. On completion of the haul the distance towed over the ground and the average values of ground speed, headline height and wing end spread were calculated.

Table I

Properties of gears

Haul No	Rig	Distance towed (km)	Mean speed (knots)	Mean headline height (m)	Mean wing end spread (m)	Length of tow (min)	No of turns*	Warp aft (m)
1	1	2.2	2.7	4.4	20.5	239	0	150
2	1	2.0	2.8	4.4	20.4	234	0	150
4	1	2.9	3.3	4.4	20.5	249	0	150
5	1	2.7	3.0	5.1	20.5	282	0	150
6	1	2.1	2.7	4.9	20.0	245	0	150
7	2	2.2	2.9	4.6	20.2	236	0	150
8	2	2.0	2.2	4.9	18.1	285	0	150
9	3	1.5	2.5	4.5	17.9	190	0	125
10	2	2.0	3.0	4.1	18.4	221	0	150
11	2	2.4	2.7	4.7	18.8	272	0	150
12	2	2.0	2.1	4.2	17.7	285	1	175
13	2	2.0	2.3	4.3	18.3	257	1	175
14	4	0.7	2.9	4.9	18.0	85	0	150
15	4	1.3	2.8	4.6	18.6	159	1	150
16	4	2.2	2.9	4.3	18.8	240	P/S	150
17	4	2.1	2.2	4.6	18.3	311	0	150
18	4	2.3	2.7	4.8	18.9	263	P	150
19	4	2.5	2.5	5.0	19.1	277	S	150
20	4	2.5	2.7	4.8	19.0	286	S	150
21	5	2.1	2.6	4.4	20.8	261	P	325
22	5	2.2	2.3	4.3	20.5	299	P/S	325
23	5	2.6	2.5	4.4	21.2	305	0	325
24	5	2.3	2.5	4.4	21.0	297	0	275
25	5	2.6	2.5	4.2	21.2	326	0	275

* S = several starboard turns
P = several port turns
1 = one turn

Results

TV Observations of Fish Behaviour

Observations on fish were made from the wing ends along the full length of the trawl to the cod-ends. The behaviour of fish relative to the gear ahead of the wings of the trawl is unknown.

The sand clouds generated by a set of polyvalent otterboards (2 by 2.5 m) sometimes came inside the trawl mouth owing to cross tides or ship and gear turning. On several occasions roundfish and flatfish in the trawl mouth were moved across the gear by the cloud, whilst in exceptional circumstances the sand cloud moved the fish right across and out of the trawl mouth on the other side. Larger otterboards (2.5 by 2.5 m) were used thereafter to ensure that the sand cloud was further away from the wing ends and never entered the mouth area even during turns.

Haddock, whiting and cod

Haddock (*Melanogrammus aeglefinus* (L.)), whiting (*Merlangius merlangus* (L.)) and cod (*Gadus morhua* L.) always entered the mouth area of the trawl within about 2 m from the sea bed. Some fish swam slowly head first into the mouth of the trawl and then turned to swim in front of the footrope, whilst others kept facing forwards but were gradually overtaken by the trawl. A series of close encounters with the trawl gear components (such as the ground gear, fishing line or netting) resulted in spurts of movement (2 to 4 m) ahead of these components. The trawl gradually overtook the fish and shepherded them into the centre of the footrope. The fish were generally within 2 m of the sea bed whilst swimming ahead of the footrope.

Dogfish

Dogfish (*Scyliorhinus canicula* (L.)) usually entered the mouth area along the sea bed tail first and moved slowly backwards along the ground gear from the wing ends into the middle section. Here they swam forward with their tails almost touching the top of the ground gear 350 mm (14 inches) off the sea bed with their heads angled down to within 75 to 150 mm (3 to 6 inches) of the sea bed. They remained close to the central ground gear components until exhausted when they slowed down and drifted into the cod-end in two to three minutes. Many were overrun by the ground gear.

Flatfish and skate

Plaice (*Pleuronectes platessa* L.), megrim (*Lepidorhombus whiffiagonis* (Walbaum)), witch (*Glyptocephalus cynoglossus* (L.)), lemon sole (*Microstomus kitt* (Walbaum)), common dab (*Limanda limanda* (L.)), long rough dab (*Hippoglossoides platessoides* (Fabricius)) and skate (*Raja batis* L.) reacted to the ground gear by swimming ahead a short distance (on average 2 m [6.5 feet]). They were then soon overtaken by another point on the ground gear nearer the centre. By this repeated process fish reached the centre where they swam near the sea bed in front of the ground gear. On exhaustion (within 20 minutes) some dived under the ground gear while others flipped over it and drifted back into the cod-end close to the belly netting. Occasionally some flatfish were observed to strike the vertical dividing line and flop towards the belly netting to one side or the other. It may be that the central vertical line splits the flatfish unevenly although the statistical results suggest this only for megrim (see below).

Analysis and Results of Fishing Trials

Gear performance

The trawl gear was monitored during each haul to ensure that the headline height and wing end spread (Table I) showed no rapid changes which might have affected the fish behaviour, especially during gear turns. Hauls 12, 13, 15, 16, 18, 19, 20, 21 and 22 had one or more turns during the tow which apparently did not affect the gear parameters to any significant extent. The rigs were as follows:

Rig 1 — double 55 m (30 fm) bridles with a single 100 m (55 fm) sweep;
Rig 2 — same as Rig 1 except two extra links added to lower bridle;
Rig 3 — same as Rig 2 except one further link added to lower bridle;
Rig 4 — same as Rig 1 except a single 37 m (20 fm) sweep used in front of the double bridles;
Rig 5 — same as Rig 2 except 29 m (16 fm) tickler chain strung between lower wing ends.

The rigs were used for different fishing areas with different sea bed conditions. The catch composition and division of species within the trawl seemed unaffected by the rig changes.

Catch data

In most cases the catches comprised mainly haddock, cod and whiting but in some hauls significant quantities of flatfish and skate were taken. Table II shows the total number of boxes of all fish caught in each cod-end in each haul, together with the ratio of the number of boxes caught on the port side to the number caught on the starboard side. The largest difference in both absolute and relative terms was for haul 10 when about a third of the boxes from each cod-end consisted of weed. The mean of the ratios for the 24 valid hauls was calculated to be 1.00 with 95% confidence limits of 0.91 and 1.10.

Table II

Numbers of boxes of fish caught by the port and starboard cod-ends in each haul and time of hauling along with an indication of the main species taken.

Haul	Port (P)	Starboard (S)	Ratio (P/S)	Day/night	Main species taken
1	14	16	0.88	Night	Haddock, cod
2	26	18	1.44	Day	Haddock, cod
3	—	—	—	Day	—
4	21	28	0.75	Night	Haddock, cod, whiting
5	17	20	0.85	Night	Cod, haddock, whiting
6	13	18	0.72	Night	Cod, haddock, whiting
7	6	7.5	0.80	Day	Cod, haddock, whiting
8	13	13	1.00	Night	Haddock, whiting
9	13	17	0.76	Night	Haddock, whiting
10	43	28	1.54	Night	Haddock, whiting
11	14	13	1.08	Day	Cod, haddock, whiting, dabs
12	13	12	1.08	Night	Haddock, whiting, skate
13	12.5	14	0.89	Night	Skate
14	24	23	1.04	Night	Cod, haddock, whiting
15	19	17	1.11	Night	Cod, haddock, whiting
16	36	26	1.38	Day	Cod
17	24	20	1.20	Day	Cod
18	19	13	1.46	Night	Cod
19	10	15	0.67	Night	Cod
20	10	11	0.91	Day	Cod
21	11	11	1.00	Day	Haddock, whiting, plaice
22	6	6	1.00	Night	Flatfish
23	7	7	1.00	Night	Flatfish
24	7	7	1.00	Day	Whiting
25	10	10	1.00	Day	Haddock, flatfish

The raised numbers of individual species caught in each cod-end, along with their ratios, are given for each haul in Table III. The ratios were examined for haddock, cod and whiting, the only species for which catches were made in a sufficient number of hauls. None of the mean values of 0.92, 1.06 and 0.85 for haddock, cod and whiting respectively differed significantly from unity.

The length frequency distributions for individual species were compared in terms of the mean length of each cod-end catch (Table III). In general, the mean lengths are closely similar. The largest difference found was in haul 25 for the average length of megrim, where only 51 fish were measured from both the port and starboard sides although the range in length was from 15 to 47 cm. A difference of 2.1 cm in mean length was found in haul 8 for haddock.

Table III

Raised number and mean length of the various fish species caught in port and starboard cod-ends

Haddock

Haul	Raised number port (P)	Raised number starboard (S)	Ratio (P/S)	Mean length (cm) port	Mean length (cm) starboard	Length difference (port–starboard)
1	956	960	1.00	31.8	32.2	−0.4
2	1,326	1,044	1.27	33.6	33.6	0.0
4	872	1,393	0.63	32.0	31.5	+0.5
5	585	936	0.62	34.2	33.3	+0.9
6	572	1,179	0.49	30.1	30.0	+0.1
7	340	360	0.94	29.1	29.0	+0.1
8	879	507	1.73	31.0	28.9	+2.1
9	992	1,899	0.52	32.6	32.0	+0.6
10	2,778	2,358	1.18	29.2	29.0	+0.2
11	305	351	0.87	30.3	29.7	+0.6
12	284	519	0.74	33.8	32.8	+1.0
14	331	570	0.58	37.4	36.5	+0.9
15	703	374	1.88	34.9	34.7	+0.2
21	249	191	1.30	33.2	34.4	−1.2
25	376	297	1.27	29.1	29.3	−0.2

Cod

Haul	Raised number port (P)	Raised number starboard (S)	Ratio (P/S)	Mean length (cm) port	Mean length (cm) starboard	Length difference (port–starboard)
1	217	296	0.73	35.1	35.4	−0.3
2	488	333	1.47	37.1	36.0	+1.1
4	373	511	0.73	39.2	39.5	−0.3
5	510	480	1.06	38.3	37.1	+1.2
6	263	266	0.99	35.6	35.9	−0.3
7	120	154	0.78	32.9	33.0	−0.1
11	389	296	1.31	34.1	34.2	−0.1
14	907	731	1.24	40.2	38.6	+1.6
15	429	456	0.94	39.1	39.0	+0.1
16	1,411	1,045	1.35	40.4	40.1	+0.3
17	1,210	1,104	1.10	38.7	38.3	+0.4
18	676	502	1.35	39.5	39.5	0.0
19	402	532	0.76	40.3	39.8	+0.5
20	376	367	1.02	38.5	39.7	−1.2

Table III (continued)

Whiting

Haul	Raised number port (P)	Raised number starboard (S)	Ratio (P/S)	Mean length (cm) port	Mean length (cm) starboard	Length difference (port–starboard)
4	294	581	0.51	31.2	30.1	+1.1
5	190	412	0.46	30.8	30.3	+0.5
6	507	770	0.66	30.5	29.7	+0.8
7	132	256	0.52	29.9	30.7	−0.8
8	1,534	1,644	0.93	28.4	27.7	+0.7
9	979	737	1.33	28.3	28.3	0.0
10	2,116	1,070	1.98	26.6	27.2	−0.6
11	400	445	0.90	28.4	29.1	−0.7
12	426	408	1.04	31.9	30.3	+1.6
14	312	515	0.61	30.9	30.1	+0.8
15	243	241	1.01	32.1	31.2	+0.9
21	90	81	1.11	32.5	33.1	−0.6
24	243	232	1.05	28.8	29.3	−0.5

Plaice

Haul	Raised number port (P)	Raised number starboard (S)	Ratio (P/S)	Mean length (cm) port	Mean length (cm) starboard	Length difference (port–starboard)
21	227	73	3.11	30.3	31.5	−1.2
22	55	46	1.20	31.0	30.4	+0.6
23	58	54	1.07	31.2	33.0	−1.8
25	66	98	0.67	30.5	30.2	+0.3

Megrim

Haul	Raised number port (P)	Raised number starboard (S)	Ratio (P/S)	Mean length (cm) port	Mean length (cm) starboard	Length difference (port–starboard)
22	14	19	0.74	37.3	38.4	−1.1
23	17	18	0.94	38.5	40.0	−1.5
25	102	102	1.00	25.3	29.7	−4.4

Table III (continued)

Witch

Haul	Raised number port (P)	Raised number starboard (S)	Ratio (P/S)	Mean length (cm) port	Mean length (cm) starboard	Length difference (port–starboard)
22	19	40	0.48	35.5	34.1	+1.4
23	11	19	0.58	31.8	31.7	+0.1
25	64	92	0.70	31.8	32.6	−0.8

Skate

Haul	Raised number port (P)	Raised number starboard (S)	Ratio (P/S)	Mean length (cm) port	Mean length (cm) starboard	Length difference (port–starboard)
12	162	114	1.42	30.8	32.5	−1.7
13	222	304	0.73	30.8	30.5	+0.3

Common Dab

Haul	Raised number port (P)	Raised number starboard (S)	Ratio (P/S)	Mean length (cm) port	Mean length (cm) starboard	Length difference (port–starboard)
11	686	910	0.75	24.1	24.7	−0.6

Further comparison of the length frequency distributions was made using "P–P" plots (Fig. 3 for cod, haddock, whiting and plaice, and Fig. 4 for skate, witch, megrim and dabs). In these P–P plots, the cumulative percentages of total numbers of fish for the port and starboard sides are plotted against each other, from the smallest to the largest length group. All hauls were combined for each species (see Table IV). Deviations from the 45° line indicate differences between the cod-ends in the size range of fish caught. There is very little deviation from the 45° line in most cases. However, for haddock in haul 8 about 35% of the fish on the port side were less than 30 cm whilst some 55% of the starboard side catch were less than this length. Nevertheless this haul was added into the combined result in Figure 3. The whiting data from haul 12 show that a greater percentage of small individuals was caught in the starboard cod-end. Although the P–P plots for the flatfish were constructed from the frequency distributions of few individuals, they do not suggest any consistent bias towards one side of the divided trawl, except possibly for megrim. The greatest deviation from the 45° line for megrim was shown, as expected, by haul 25, but it was added into the combined result in Figure 4.

Table IV

List of combined haul numbers used in the P–P plots (see also Figs 3 and 4)

Haul	No of hauls combined in plots	Haul numbers
Cod	14	1, 2, 4, 5, 6, 7, 11, 14, 15, 16, 17, 18, 19, 20
Haddock	15	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 21, 25
Whiting	13	4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 21, 24
Plaice	4	21, 22, 23, 25
Skate	2	12, 13,
Witch	3	22, 23, 25
Megrim	3	22, 23, 25
Dabs	1	11

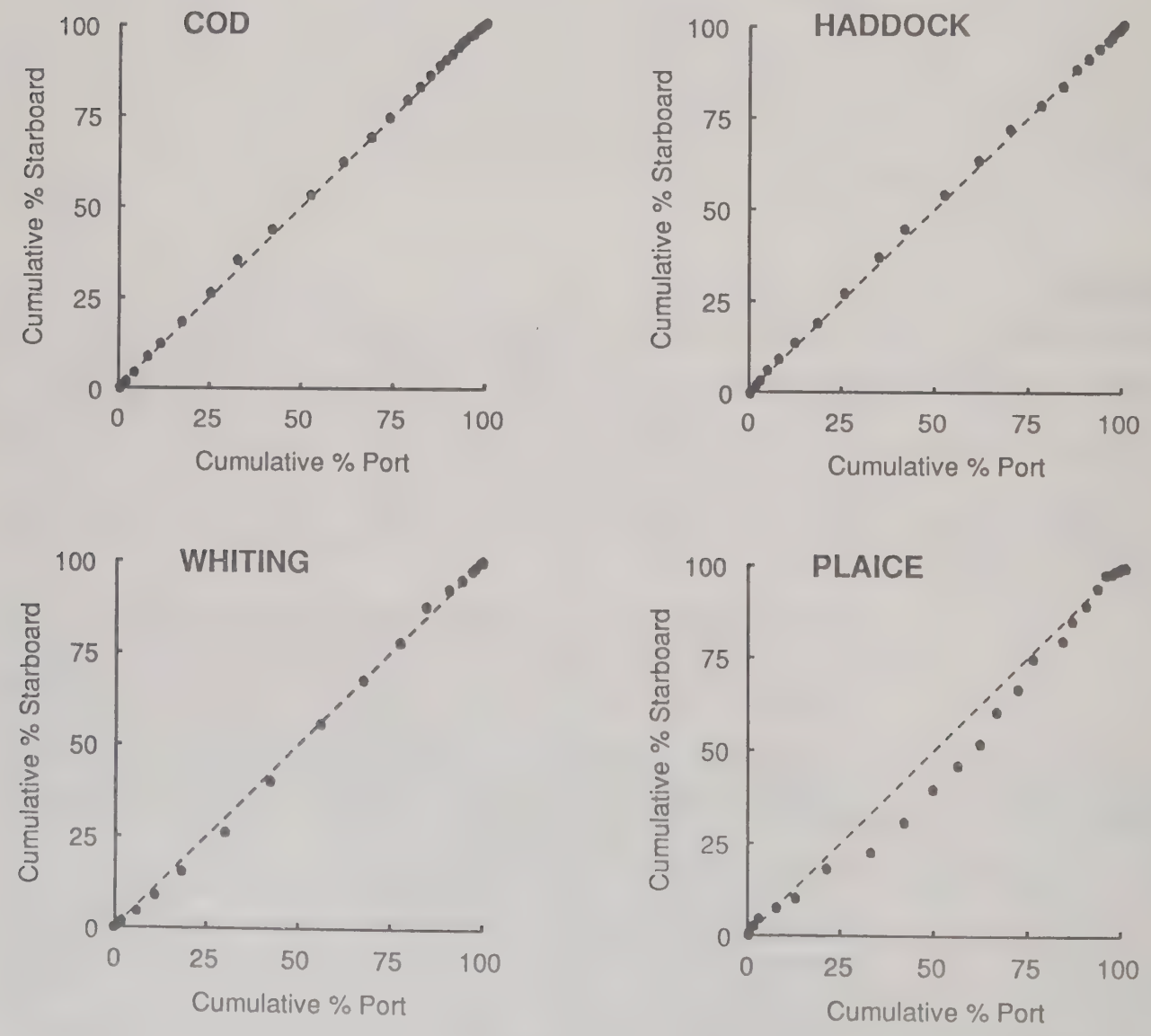

Figure 3. A comparison of length distributions of cod, haddock, whiting and plaice caught in the port and starboard cod-ends

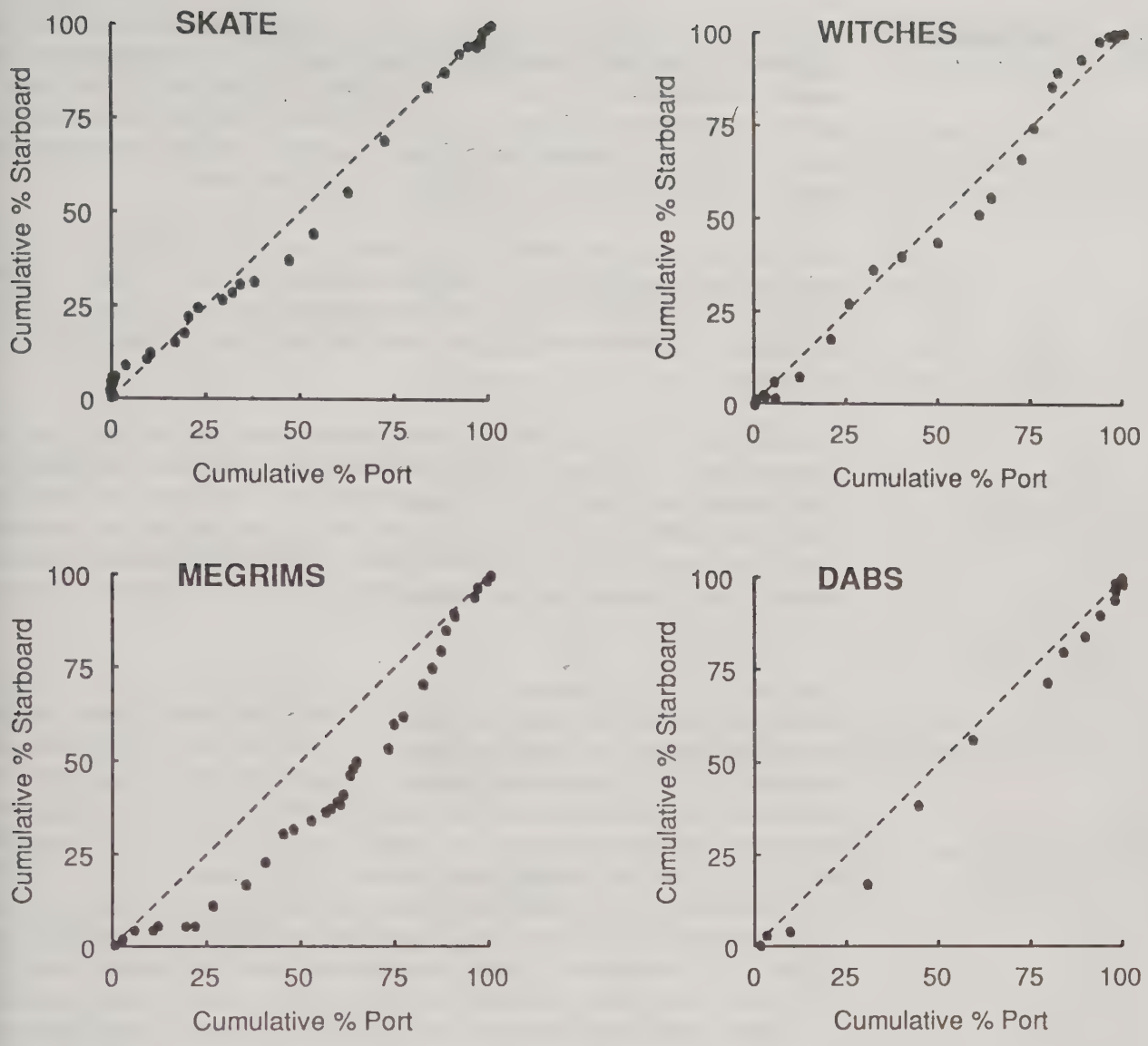

Figure 4. A comparison of length distributions of skate, witch, megrim and dabs caught in the port and starboard cod-ends

Conclusions

There was no visual or quantitative evidence to suggest bias in the catchin efficiency of the two sides (port and starboard) of the divided trawl. Fis reaction was similar to that seen with ordinary trawl gear. There was n significant difference in the total number of boxes caught in each cod-en and the length compositions of cod, haddock, whiting, skate and fou species of flatfish were similar in each side of the trawl.

The technique may be used for the measurement of the selectivity parame ters of a test cod-end, using a small mesh cod-end on one side. It seem justifiable, therefore, to also use the technique for comparing the lengt frequency distributions of catches in two cod-ends, eg of different mesh siz or design.

There are two provisos. First, as with the alternate haul method, the sma mesh cod-end used to sample the population in a selection experiment ma catch fewer fish of some length groups than does the test cod-end. Thi implies percentage retentions of more than 100% by the test cod-en Statistical treatments to overcome these anomalies may be necessary. Alternatively, the combination of groups of consecutive hauls may eliminat the problem.

The second proviso applies to both a selectivity experiment and a catc comparison trial. The cod-ends on the two sides may retain differen quantities of fish or have different drag for other reasons, eg differences i construction. This imbalance may be sufficient to affect the selectivity of th cod-ends or the distribution of fish between them. For example, a recent tria suggested that the selection characteristics of the small mesh cod-end sid of the trawl were changed, resulting in a much reduced catch of plaic (unpublished data). The footrope may become lighter on the sea bed unde the influence of the greater bulk of mixed species in the small mesh cod-en Under this circumstance more plaice would tend to escape under th footrope on that side of the gear because of their behaviour of swimmin very close to the sea bed whilst being herded in front of the groundgea (John Main, personal communication). However, in these trials similar coc ends were used and it is likely therefore that reliable selection or catc comparison results will be obtained when the contents and drag of the tw cod-ends do not differ by large amounts. If this condition is met the divide trawl technique should give better estimates of selectivity parameters tha either the alternate haul or covered cod-end methods. However, it is likel that the method would be better used as a catch comparison techniqu where the two cod-ends being compared retain similar quantities of fish.

Acknowledgements

Our thanks are due to skipper Tom Harcus and crew of the "Orkney Reiver for the excellent job they did during the experiments.

Summary

A divided trawl was constructed to tow two cod-ends side by side for mes selection studies and catch comparisons. The net was divided from th headline and footrope aft, and designed to resist asymmetric operation Before using the net in comparative studies it was necessary to prove tha the two sides fished equally. Under-water observations of fish reactions an the results of fishing trials with identical cod-ends suggest symmetri fishing performance except in respect of some flatfish species for which possible reasons are discussed.

References

Beverton, R.J.H. and Holt, S.J. 1957. On the dynamics of exploited fish populations. *Fishery Investigations, London, Series 2*, **19**, 533pp.

Cooper, C.G. and Hickey, W.M. 1987. Selectivity experiments with square mesh cod-ends on haddock and cod. *Department of Fisheries and Oceans, Halifax, Canada*, Report Number CH2498-4/87/3pp.

Davis, F.M. 1934. Mesh experiments with trawls 1928—33. *Fishery Investigations, London, Series* 2, **14**(1), 56pp.

Herrington, W.C. 1936. Modifications in gear to curtail the destruction of undersized fish in otter trawling. *US Bureau of Fisheries, Investigational Reports*, **1**(24), 1936.

Pope, J.A., Margetts, A.R., Hamley, J.M. and Akyuz, E.F. 1975. Manual of methods for fish stock assessment. Part III. Selectivity of fishing gear. *FAO Fisheries Technical Paper*, (41) (Revision 1), 15pp.

Priestley, R., Wardle, C.S. and Hall, C.D. 1985. The Marine Laboratory remote controlled fishing gear observation vehicle. *International Council for the Exploration of the Sea* CM 1985/B:10.

Russell, E.S. and Edser, T. 1926. The relation between cod-end mesh and size of fish caught; preliminary experiments with the trouser trawl. *Journal du Conseil*, **1**(1), 39—54.

Smolowitz, R.J. 1983. Mesh size and the New England ground fishery applications and implications. *NOAA Technical Report*, NMFS SSRF-771, July 1983, 15pp.

Printed in Scotland by HMSO Reprographic Unit, Edinburgh
1m 10/90 (029352)

1984 No. 31 A Selected Review of Hydrodynamic Force Coefficient Data on Stranded Wires Used in Fishing Gear.
By R.S.T. Ferro and E.H. Hou, 20 pp.

1985 No. 32 Small Mesh Cod-end Covers.
By P.A.M. Stewart and J.H.B. Robertson, 11 pp.

No. 33 Attachments to Cod-ends.
By P.A.M. Stewart and J.H.B. Robertson, 15 pp.

No. 34 The Behaviour of the Norway Lobster, *Nephrops norvegicus* (L.), During Trawling.
By J. Main and G.I. Sangster, 23 pp.

No. 35 Experiments on the Cultivation of Oysters in Scotland.
By J. Drinkwater and T.R.W. Howell, 20 pp.

1986 No. 36 Radio-Tracking Observations on Atlantic Salmon Ascending the Aberdeenshire Dee.
By A.D. Hawkins and G.W. Smith, 24 pp.

1987 No. 37 A Model to Assess the Effect of Predation by Sawbill Ducks on the Salmon Stock of the River North Esk.
By W.M. Shearer, R.M. Cook, D.A. Dunkley, J.C. MacLean and R.G.J. Shelton, 12 pp.

1988 No. 38 The Intertidal Fauna of Sandy Beaches — A Survey of the East Scottish Coast.
By A. Eleftheriou and M.R. Robertson, 52 pp.

No. 39 Mesh Selection Within the Cod-end of Trawls. The Effects of Narrowing the Cod-end and Shortening the Extension.
By J.H.B. Robertson and R.S.T. Ferro, 11 pp.

1989 No. 40 The Movements and Spawning Behaviour of Adult Salmon in the Girnock Burn, A Tributary of the Aberdeenshire Dee, 1986.
By John Webb and A.D. Hawkins, 42 pp.

No. 41 The Movements of Adult Salmon within the River Spey.
By Robert Laughton, 19 pp.

No. 42 Genetic Protein Variation in Farmed Atlantic Salmon in Scotland: Comparison of Farmed Strains with their Wild Source Populations.
By A.F. Youngson, S.A.M. Martin, W.C. Jordan and E. Verspoor, 12 pp.

No. 43 Length/Weight Relationships for 88 Species of Fish Encountered in the North East Atlantic.
By K.A. Coull, A.S. Jermyn, A.W. Newton, G.I. Henderson and W.B. Hall, 81 pp.

No. 44 The Movements of Adult Atlantic Salmon in the River Tay.
By John Webb, 32 pp.

No. 45 Records of Porbeagles Landed in Scotland, with Observations on the Biology, Distribution and Exploitation of the Species.
By J.A. Gauld, 15 pp.

1990 No. 46 An Assessment of the Scale Damage to and Survival Rates of Young Gadoid Fish Escaping from the Cod-end of a Demersal Trawl.
By J. Main and G.I. Sangster, 28 pp.

No. 47 Force Coefficients for Stranded and Smooth Cables.
By R.S.T. Ferro, 10 pp.

No. 48 The Behaviour of Adult Atlantic Salmon Ascending the Rivers Tay and Tummel to Pitlochry Dam.
By John Webb, 27 pp.

Available from:–

The Librarian
Department of Agriculture & Fisheries for Scotland
Marine Laboratory
PO Box 101
Victoria Road
Torry,
Aberdeen AB9 8DB.